

MARICULTURE COMMITTEE

by

K. Tiews

1978

Belgium

(F. Redant)

The research programmes carried out jointly by the Institute for Marine Scientific Research (IZWO) and the laboratory for Mariculture at the State University of Ghent focused on two pilot-scale operations for the controlled mass culturing of the brine shrimp Artemia salina and the nursery culturing of edible molluscs.

<sup>3</sup> The pilot-scale on Artemia consists of 4 race-ways of 5 m<sup>2</sup>, the medium of which is heated electrically as a simulation for the utilization of thermal effluents.

This program also aims at the recycling of several types of biodegradable agricultural wastes into a valuable protein and high priced biomass.

The pilot-scale nursery consists of 4 outdoor race-ways of 100 m<sup>2</sup> surface (+ 100 m<sup>3</sup> contenance) for mass production of natural phytoplankton (with different mechanisms for the circulation<sub>2</sub> of the culturing<sub>3</sub> medium) and 4 indoor race-ways of 3 m<sup>2</sup> surface (1.5 m<sup>3</sup> contenance) to grow the mollusc spat.

Experiments will be carried out on a year-round basis to determine the growth of different species of juvenile molluscs in heated (simulation of thermal effluents) and non-heated raceways.

At the Artemia Reference Center in the Laboratory for Mariculture at the State University of Ghent experiments are in progress (in collaboration with different foreign laboratories and Institutes) for the culturing of Artemia on algae produced in coastal upwelling systems. The utilization of heated brine from geothermal origin is also considered.

At the Fisheries Research Station, Ostend, a feasibility study on the culture of juvenile plaice (Pleuronectes platessa) and sole (Solea solea) was carried out.

The European Mariculture Society EMS (the registered office of which is located at the Institute for Marine Scientific Research) further endeavoured to disseminate maricultural information through its Quarterly Newsletters and Special Publications.

Canada  
(J.E. Stewart)

Studies and development work in Canada in the general subject area of Mariculture are extensive and diverse. Considerable effort is being expended on salmonid culture and sea ranching on both the Atlantic and Pacific coasts. Preliminary trials with lobsters utilizing techniques for accelerated growth are underway; Blue mussel culture is now being attempted in a small way commercially following a number of years of successful development work based on European technology. Evaluation of the possibilities inherent in European Flat Oysters, Quahaugs and Bay Scallops is proceeding. Culture of the local Atlantic oyster species Crassostrea virginica has increased over the past few years.

Research work is being conducted at several locations on both coasts to learn as much as possible about the biology of a variety of species, to gain information on rates of growth, parasites, diseases, nutritional requirements, physiology, genetics, maturation, fecundity, bio-energetics ecology, etc., for use in fisheries management and where and when possible applied to mariculture. Some aspects of the research work, when prospects appear promising, are focused directly on the mariculture aspects.

The following account of various projects is representative of the sea water culture work in Canada either on the commercial side or in the evaluation stages and is supported generally by the relevant research activities listed above:

Atlantic Coast

Salmonids

There is a marked increase in interest and activity in salmonid aquaculture in both fresh and salt water. Presently seventeen commercial operations of varying scale are licensed in the Maritimes and six more are in planning or construction stages, some of considerable size.

The largest commercial company, a 7 year old operation growing rainbow trout in marine cages in Nova Scotia marketed over 75 tons of pan-sized fish in 1978 and one ton of larger fish, returns from accidental escape. These fish were largely from imported eggs but the company plans to be self sufficient for eggs in the near future. Atlantic salmon are currently being reared to assess the potential for cage rearing and sea-ranching.

A joint federal-provincial-private operation at Deer Island in the Bay of Fundy has completed a year of operation. This site offers a potential for good survival overwinter, a factor which has been shown to be a severe restriction to marine cage rearing in Eastern Canada. Pilot commercial

feasibility studies were carried out on a number of species. Brook trout and a number of salmonid hybrids showed heavy mortalities during and after acclimation to seawater. Rainbow trout showed good growth and have been marketed. Atlantic and pink salmon have shown excellent growth and, to date, good survival in a winter which has been severe in some respects.

A pilot provincial marine cage project using rainbow trout in Prince Edward Island has demonstrated one promising site. Private commercial participation in an expanded continuation of this project is anticipated in 1979.

General experience in Marine salmonid culture has demonstrated priority needs to be effective vaccination against Vibrio sp., and advances in cage design to better control escapes and cope with fouling and icing problems.

#### Molluscs

Blue Mussels. As an outgrowth of provincial pilot studies in Nova Scotia, one commercial operator using a long line technique produced 15 tons of mussels in 1978 and expects to triple this in 1979.

In Prince Edward Island a number of private operations, one of considerable size, have developed following 4 years of provincial studies.

#### European Flat Oysters

In the provincial development project, techniques have been developed to overcome the winter mortalities formerly experienced and private commercial operations have been established. Projects in development and evaluation of hatchery techniques and genetic improvement are underway. An apparent potential for seed export to Europe is being pursued.

#### Quahaugs

The hard clam is under evaluation in P. E. I. in a provincial project developing and assessing hatchery, nursery, and planting techniques for commercial applicability.

#### Bay Scallop

Quarantine facilities have been built and tested for a trial introduction of this species to Prince Edward Island to assess its commercial potential via hatchery breeding from quarantined stock.

#### Crustacea

##### Lobsters

Following the potential, demonstrated in an earlier contract study, for the commercial "growing on" of ablated lobsters to achieve more valuable sizes

and exploit seasonal market fluctuations, a private company in Prince Edward Island is making further studies under federal contract. This project will develop and evaluate equipment, techniques and diets, assess economic parameters and produce operating guidelines for commercial application.

#### Pacific Coast Salmon

A large number of Coho salmon (150 000) were reared to a size range of 20-100g under accelerated regimes achieving an 85% survival. These fish were released after 80% had been treated with the odour cue morpholine to test homing capacity and as a contribution the local sports fishery.

Chinook salmon have been raised in seapens and matured after two years in sea water. A number were not stripped this year but are being kept for the third year.

A domestic strain of Rainbow trout grown at 14C were found to have the highest growth rate and best saltwater adaptation. Seapen rearing began in December at 40g with the first marketable size (250g) expected 12-14 months from hatching. This species shows excellent potential as a "filler species" since its reproductive cycle is approximately 6 months removed from Pacific salmon, thus virtually eliminating "down time" in the hatchery.

Survival and homing of accelerated growth, seapen reared Pacific salmon (Coho, Chinook and Sockeye) from Departure Bay has been poor over the three year trial period. This incidental finding is important in assessing possible success of ocean ranching of seapen reared Pacific salmon

#### Denmark

(E. Hoffmann)

#### Fish Cultivation

In 1978 a small scale experiment concerning the rearing of rainbow trout in heated effluents from a conventional power plant was started in Kolding Fjord. It is planned to include rearing of the oyster Crassostrea gigas in 1979.

In the Marine Laboratory in Elsinore a programme with turbot Scophthalmus maximus has been started in 1978. The purpose of the project is, among others, to obtain high survival rates from egg to metamorphosis.

A number of commercial fish farms in marine waters has started up in 1978. All of these farms produce rainbow trout. It is expected that the number of Danish marine trout farms will increase during the next few years.



## Shellfish

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A hatching system including rearing tanks for the European lobster Homarus vulgaris has been developed in the Marine Laboratory in Elsinore.

A rearing program has been carried out successfully in 1978.

In the Limfjord a transplantation program with Mytilus edulis has started up. The mussels are fished in areas with high population densities and then moved by boat to areas suitable for Mytilus, but with low population densities.

## Finland

(P. Tuunainen)

The four year's period of experiments with the rearing of Baltic salmon (Salmo salar) smolts for stocking purposes in the brackish (6 ‰) cooling water of an electric power plant was completed in 1978. The results have been very promising and plans have been made to construct a larger experimental fish farm in connection with a nuclear power plant.

The Finnish fish farms have a shortage of salmon eggs because many of the natural stocks of Baltic salmon have died out as a consequence of construction of dams in their spawning rivers or the number of the spawners has been decreased because of the heavy fishing pressure in the sea. Because of the lack of eggs from wild fish salmon are reared in fresh water fish farms for production of eggs. However, the quality of eggs produced in this way is not very good. Therefore experiments are going on to rear salmon in net cages in brackish water for this purpose. Also salmon smolts have been introduced into the Baltic at the mouths of such rivers, where the capture of the spawners can be arranged.

To increase the stocks of salmon and sea-trout (Salmo trutta trutta) in the Baltic introductions of smolts have been increased year by year. In addition a salmon river, Simojoki River, flowing into the Gulf of Bothnia was restored after the log floating had been finished in it. After restoration the densities of salmon parrs in the rapids increased remarkably. Restoration of some tributaries of Tornionjoki River, also flowing into the Gulf of Bothnia, began in 1978. Before clearing the rapids of stones for log floating these tributaries have been important spawning rivers for sea-trout.

The commercial production of rainbow trout (Salmo gairdneri) in net cages in Finland's south-western archipelago is continually increasing, amounting 300-400 t in 1978.

### France

(J. Audouin et L. Laubier)

#### A) Poissons (L. Laubier)

##### 1. POISSONS SALMONIDES

L'activité a été concentrée en ce qui concerne l'élevage en mer du saumon Coho (Oncorhynchus kisutch) sur l'étude de la gamétogenèse et de la ponte en captivité, et dans une moindre mesure sur les problèmes de déséquilibre physiologique estival en eau de mer à salinité élevée, en fonction de la nourriture. Pour les élevages de truites arc-en-ciel (Salmo gairdneri), les travaux ont porté sur la détermination de la taille de passage brusque de l'eau douce à l'eau de mer.

##### 2. POISSONS MARINS

###### 2.1. Bar (Dicentrarchus labrax)

On doit d'abord souligner l'accroissement de la production totale d'alevins : plus de 700 000 alevins ont été produits en 1978, dans différents établissements publics ou privés. On peut escompter une production commerciale correspondante d'une dizaine de tonnes en fin d'année 1979. On a poursuivi les études sur l'amélioration des aliments composés sous forme de microparticules pour les larves de bar.

## 2.2. Daurade (Sparus auratus)

L'effort a principalement porté sur le développement larvaire. La production d'alevins a atteint en 1978 20 000 juvéniles, et la survie depuis l'oeuf a atteint dans certains cas 10 %. Il semble donc que certains problèmes d'alimentation et de conditions générales d'élevage posés depuis 1970 sont en voie d'être résolus.

## 2.3. Sole (Solea solea)

Il a été produit plus de 20 000 juvéniles de soles (quelques grammes de poids individuel) conditionnés à consommer en aliment sec sous forme de granulé, avec 20 % de survie depuis l'éclosion des larves. Les résultats permettent, tout au moins au plan scientifique et technique, d'envisager la réalisation d'une écloserie pilote de soles.

## 2.4. Turbot (Psetta maxima)

En matière de croissance avec utilisation d'aliments composés, on a obtenu de bons résultats, en bassins et en cages. Les difficultés enregistrées au cours des années précédentes en matière d'élevage larvaire n'ont toujours pas été résolues, et les taux de survie obtenue demeurent très faibles.

## B) Mollusques, Algues et Crustacés (J. Audouin)

### Mollusques

#### Pectenidés. Expériences de captage

Pecten maximus : 25 000 collecteurs ont été immergés en baie de St Brieuc.

La fixation a été tardive et le rendement du captage a été compris entre 10 et 30 par collecteur.

2000 collecteurs ont été placés en Rade de Brest et Baie de Camaret : il n'y a pas eu de fixation.

Lors d'une opération de repeuplement on a observé un taux de survie de 50%, 15 mois après le semis.

Ces expériences ont été effectuées par le CNEOX en collaboration avec les organismes professionnels locaux.

#### Chlamys varia et Chlamys opercularis.

En rade de Brest, 3000 collecteurs ont été utilisées. On a observé deux fixations principales, la première a donné 5 à 700 Chlamys varia par collecteur la seconde 3000. (Comité local des Pêches Maritimes et CNEOX).

3000 collecteurs ont été immergés en Baie de Quiberon (ISTPM). Les résultats du captage ont été faibles comme l'année précédente. Le naissain obtenu, destiné au secteur de Ré-Oléron a été placé en prégrossissement dans des "lanternes japonaises".

### Veneridés :

Des expériences d'élevage en surélévation de Ruditapes decussata, Ruditapes philippinarum et Mercenaria mercenaria, commencées en 1974 se sont poursuivies. Dans les sites retenus, la croissance observée a été trop lente pour justifier une extension de ce type d'élevage.

En revanche, de meilleurs résultats ont été obtenus en claires et en lagunes sur les deux espèces de palourdes précitées. Ces essais ont porté sur 30 000 Ruditapes decussata (ISTPM LA TREBLADE).

A l'Ile d'Yeu (CNEXO-COB) des expériences portant sur plus de 120 000 Ruditapes philippinarum ont montré un taux de survie allant de 25 à 65% selon la taille initiale du naissain provenant d'écloserie. La taille de 7 mois au semis semble être le minimum permettant un taux de survie supérieur à 50% après 16 mois d'élevage.

### Paliotidés

Des ormeaux de 18 à 25 mois provenant de l'Écloserie d'Argenton (CNEXO-COB) ont été mis en place à densités variables dans des habitats artificiels en Bretagne Nord. Le taux de recapture 9 mois après l'immersion a atteint 70%.

### Algues :

L'étude des possibilités de cultures en bassins de l'algue rouge Chondrus crispus a été poursuivie en 1978 et une comparaison des résultats obtenus en circuits ouvert et semi-fermé a été faite (ISTPM).

Un traitement préventif contre les épiphytes a été utilisé avec succès. Cependant, l'ensemble des résultats conduit à une production maximale de 25 à 30 tonnes par hectare et par an, qui ne permet pas d'atteindre la rentabilité. La recherche de variétés à croissance plus élevée que la moyenne est envisagée.

### Crustacés.

#### Homards.

La production de post-larves des Écloseries a été la suivante en 1978

-Écloserie de l'Ile d'Yeu (ISTPM) :	120 000
-Écloserie de l'Ile de Houat :	35 000
-Écloserie de l'Ile de Sein :	30 000

L'étude comparative de la croissance en captivité du homard européen, du homard américain et des hybrides s'est poursuivie (ISTPM).

#### Langoustes.

Une étude de la croissance en captivité de la langouste Palinurus elephas a été entreprise (ISTPM)

Orevettes.

Une étude de la physiologie des larves de Penaeus japonicus a été entreprise (CMEKO-COB). Elle a porté sur les points suivants :

-mesure des besoins respiratoires des différents stades larvaires en fonction de la température.

-mesure de l'ingestion des larves en fonction de leurs poids aux différents stades.

Ceci a conduit à établir le bilan énergétique des stades nauplius, zoé, et Mysis. Ces recherches permettent de déterminer le niveau de concentration de la nourriture et les besoins en oxygène au cours de l'élevage.

Un travail de biométrie destiné à apprécier la variabilité génétique de la descendance d'une même femelle de Penaeus japonicus, au cours des générations successives en élevage, a été commencé.

Une étude a été entreprise concernant les conditions de maturation ovarienne de Penaeus vannamei.

German Democratic Republic

(W. Loos)

In 1978 the following scientific and technical tasks have been carried out in the fields of marine aquaculture:

1. Development of a procedure for the production of rainbow trout fingerlings in floating cages being placed in naturally tempered brackish water. The experiments carried out with a salt content between 7,5 ‰ and 10,5 ‰ as well as with a temperature of the water between 7 °C and 23 °C have been successful (Weight of fish at the start of the experiment being 1 g). The applied technique (net cages, feeding machines) has been successful.
2. Utilisation of heated brackish cooling water of a power station for the production of rainbow trout fingerlings in winter. Experiments of rearing the fry of rainbow trout have been initiated without additional improvement of the water.
3. Culturing of a rainbow trout stock being resistant against diseases in the brackish water. First results show an increased stability against Vibriosis and other bacterial diseases.
4. Investigation of salt content toleration concerning the fry of Hypophthalmichthys molytrix and Aristichthys nobilis. First results show that the mortality will be significantly increased if the salt content exceeds 4 - 6 ‰.



Federal Republic of Germany  
(K. Tiews)

Mytilus edulis:

Raft culture experiments in power plant effluents in the Kiel Bight were continued as well as the use of Mytilus as fish feed in rainbow trout fattening experiments at the same installation (Institut für Meereskunde, Kiel).

Crassostrea gigas:

Indoor experiments on the reproduction and rearing of spat were continued as well as out-door experiments on the fattening of spat to marketable sizes. An experimental station was built at Langballigau near Flensburg.

Container culture experiments on various places along the German North Sea and Baltic coasts were also continued.  
(Institut für Küsten- und Binnenfischerei, Hamburg).

Fish nutrition:

Work was continued on the development of fish feeds for rainbow trouts in which fishmeal as protein source was substituted by other conventional and unconventional protein sources (Institut für Küsten- und Binnenfischerei, Hamburg; Institut für Meereskunde, Kiel). Also the development of eel feeds was continued (Institut für Küsten- und Binnenfischerei, Hamburg).

Utilization of warm water effluents of power stations for mariculture:

Apart from the work described under Mytilus, growth and rearing experiments of Anguilla anguilla, Siganides, Dicentrarchus labrax, Tilapia zilli and Tilapia mosambica was continued at the experimental station Emden of the Institut für Küsten- und

Binnenfischerei as well as cage farming experiments of salmonid fish in the western Baltic by the Institut für Meereskunde, Kiel and the Institut für Küsten- und Binnenfischerei, Hamburg.

#### Recirculating seawater systems:

Work on the development of a recirculating sea water systems was continued at the Institut für Küsten- und Binnenfischerei and the Biologische Anstalt Helgoland, Hamburg.

#### Marine bio-production:

Work on the development of technics for the mariculture of marine invertebrates was continued at the Kiel-Bülck station of the Institut für Meereskunde, Kiel.

#### Fish pathology

Work to develop methods with which to describe stress conditions for fish in intensive aquaculture systems was started at the Institut für Hydrobiologie und Fischereiwissenschaft of the University of Hamburg. In an initial phase work concentrated on eels.

Vaccination experiments of rainbow trouts kept in cages in the Flensburg fjord, Eckernförde Fjord and Kiel fjord were carried out at the Institut für Küsten- und Binnenfischerei, Hamburg.

#### Cage farming experiments

Cage farming experiments with rainbow trouts were continued in the Flensburg fjord and the Eckernförde Fjord at the Institut für Küsten- und Binnenfischerei, Hamburg.

### Iceland

(Fisheries Association of Iceland (I. Jóhannsson)

In 1978 experiments in farming salmon in floating cages were carried out in two places. On the south coast at Hafnir on Cape Reykjanes and in the north country at estuary Lake Lón in the district Kelduhverfi. In both places the salmon were fed on dry pellets. Experiments are still taking place at Lón in Kelduhverfi.

A company, established in 1978 in Grindavík on Cape Reykjanes has had charge of experiments in salmon farming in salt water in tanks on land. Salt water from drill holes is pumped into the feeding tanks.

Ireland

No report received

Netherlands

( Th. J. Tienstra and M. Fonds )

A) Ministerie van Landbouw en Visserij  
Directoraat-Generaal voor Landinrichting, Grond-en Bosbeheer  
(Th. T. Tienstra)

I. A study carried out by Mr. R. Dijkema

a. The feasibility of seafish farming

In 1978 a study has been started to assess the possibilities and the potential of the commercial farming of seafish in the Netherlands. This study concerns coastal aquaculture as well as the use of cooling water for aquacultural purposes.

For coastal water aquaculture the temperature range of the coastal water allows exclusively the culture of coldwater species like Salmonids, and even this culture will have to face the risk of the occurrence of cold water mortality about once each nine year. Besides, in most areas summer water temperatures in some years exceed 20°C. Counting in this kind of losses a rainbow trout farming operation with a production of 100 tons/year could become profitable within 3 - 4 years. For Atlantic salmon the break-even point would lie at a yearly production of about 50 tons.

An advantage is the extension of the growing season which, in the Dutch coastal waters, is considerably longer than e.g. in Norway. Disadvantages are the before mentioned sea water temperature ranges, the paucity of suitable, sheltered areas, water pollution and recreational pressure.

Culture in cooling water of flatfish species (sole and turbot) could possibly become feasible once the present bottlenecks in the research and development of these cultures: larval production, larval mortality and early feeding, have been cleared away. In the Netherlands a relatively small amount of cooling water producers (power stations and some big industries) is to be found. Investments will be rather high due to the need to transport cooling water from power plant to farm and high ground prices. The break-even point of a sole farming operation will probably lie at a yearly production of 200 tons, for turbot higher. Prospects for salt-water eel farming in cooling water look more realistic than those of flatfish farming, as a consequence of a more reliable supply of prime material, proven feasibility in other European countries, a good product price level and the immediate presence of trade and processing industry.

b. Recent developments in aquacultural activities

After years of reserve interest in investments in aquaculture is showing. A sea-cage operation of rainbow trout farming, combined with off-bottom culture of mussels (Mytilus edulis) will start operating in the Wadden Sea area in spring 1979. The enterprise will partly be subsidized by the Dutch government.

A pilot plant for salt-water culture of European eel in the cooling water of a big industry in the Northern part of the country has been scheduled to start may 1979.

II. A study carried out by the Netherlands Institute for Sea Research

a. Solea solea

Soles spawned regularly in the tanks in the laboratory, but the eggs were always unfertilized in spite of the presence of adult males. We suspect that the ripe females excrete hormones which prevent maturation of the males when the fish are kept crowded. Males and females are now kept separately during winter.

b. Platichthys flesus

During March eggs of flounders were artificially fertilized in the laboratory and the rate of development was measured at 5°, 10°, 15°C. The larvae were reared at 10 to 15°C with Brachionus and wild plankton, they metamorphosed at about 10-11 mm length.

c. Food intake measurements

During 1978 the maximum daily food intake and the metabolism was measured of plaice (P. platessa), flounder (P. flesus) and shrimp (Crangon crangon) at constant temperatures of 10, 14, 18, 22°C.

The daily food intake of feeding fish, weight loss of starving fish and the oxygen uptake, are described as functions of the size of the fish and the water temperature, in order to estimate food intake in the sea.

B) Nederlands Instituut voor Onderzoek der Zee (M. Fonds)

1. Soles (S. solea) spawned regularly in Spring in the laboratory but the eggs were always unfertilized in spite of the presence of males. Males and females are now kept separated during winter, since the possibility exists that the ripening females excrete hormones which prevent ripening of the males when they are kept crowded.

2. Flounder eggs (P. flesus) were artificially fertilized in the laboratory and incubated at 5, 10, 15 °C (30 /ooS). The larvae were reared at 10 - 15 °C with Brachionus and natural zooplankton, until they metamorphosed at 11 mm total length.

3. The daily food intake, growth and oxygen consumption of plaice (P. platessa), flounder (P. flesus) and shrimp (C. crangon) was measured in the laboratory at different constant temperatures following the seasonal fluctuation of the temperature in the sea. We are trying to develop models which may predict or estimate the food consumption of these species in the sea.

Norway  
(G. Nævdal)

The long-term projects concerning salmonids run by the Institute of Marine Research, Bergen, have been continued in accordance with the guidelines drawn up in the previous years, except that some experiments were interrupted because the research fish were infected with IPN-virus (see later).

A new field research station, Akvakulturstasjonen Austevoll, situated in Austevoll, about 50 km south of Bergen, was set in operation in 1978. This station is equipped for field research in marine fish farming, rearing of larvae of marine fish species, mussel farming and laboratory experiments on bioenergetics. Experiments within these fields were started in summer and autumn 1978.

The experiments at the research station Akvakulturstasjonen Matre were interrupted in 1978 because IPN virus was detected within the research fish material. New material was reared at a provisional station, and Akvakulturstasjonen Matre was emptied, disinfected and the new material was transferred to the station a month later (August). The infected material will be reared to food fish size at selected commercial fish farms, but it can not be used for brood stock since the IPN virus is easily transferred by the eggs. The interruption had a serious effect for some of the research projects at the station, i.e. the experiments on selective breeding and of salmon release.



Tentative results indicate that the smolt leave for the sea during a very short period and that they migrate in small schools. The fish seem to be feeding on plancton in the bays for some time after leaving the river. The investigation will be continued in 1979.

A pilot-scale investigation of Atlantic salmon escapement from and bruising in monofilament and multifilament nets was made in the gantry tank at the Institute of Marine Research, Bergen. The study is part of a larger investigation of damages on the salmon stocks of Norway which is going to be made in cooperation with the Directorate of Game and Freshwater Fish in 1979.

#### Pathology.

In 1978 the work has mainly been on three topics: Vaccination of farmed salmonids against vibriosis, bath-treatment of salmonids attacked by salmon lice (Lepeophtheirus salmonis) and pseudobranchial tumors in cod.

Good results of vaccination have been obtained with cell fragments distributed through bath.

Two methods of bath treatment with Neguvon<sup>R</sup> against salmon lice have been described both being highly effective and harmless for the fish.

The occurrence of pseudobranchial tumors in cod in the Barents sea has been surveyed.

## RESEARCH PROJECTS

### Quantitative genetics.

Experiments with selective breeding of Atlantic salmon and rainbow trout have continued at the Institute of Marine Research, Bergen. The field experiments are carried out at Akvakulturstasjonen Austevoll and Akvakulturstasjonen Matre and at commercial fish farms.

New material was collected from rivers and fish farms in 1977 and 1978 because the "old" material was infected by IPN virus. Observations from this previous material, i.e. effect of selection, are still collected, but the fish can not be further used for producing an improved brood stock. The "new" material will be used both for producing improved brood stock for farming of Atlantic salmon and rainbow trout, and for studying genetic variation in survival and return rate of released fish.

### Behaviour.

Aggression and growth of hatchery reared Atlantic salmon parr of different river origin was studied in aquaria. Clear differences in the behaviour of the groups were found and results suggest that growth differences between populations in aquacultural conditions to some extent are mediated via behavioural differences.

A pre-experiment in studying the migratory behaviour of Atlantic salmon smolt was carried out in the estuary and in the sea outside the river Lone, Western Norway. Nine fish were tagged with small acoustic transmitters and the movements of the fish were followed by picking up the signals with hydrophones mounted on a boat.

Physiology and nutrition.

Early growth rate of introduced pink salmon, Oncorhynchus gorbuscha, was studied at different salinities and by using commercial dry food and natural food (Calanus).

The effect of feeding frequency on growth rate and food conversion was determined for young rainbow trout. Fish weighing 3,5 - 120 grams were fed ad libitum 1 - 8 times a day during 5, 6 or 7 days a week.

In two experimental series rainbow trout were fed wet diet with six vitamins supplemented according to NRC - recommendations. One fish group received all vitamins, six groups received all but one, and one group received no vitamin supplement. The two experimental series lasted for 5 and 7,5 months respectively.

Comparative studies on various types of salmonid feeds (commercial dry food, moist pellets and wet feed were carried out in sea cages).

Experiments with use of binders in salmonid feed and with silage conservation of such feed were started.

Laboratory experiments on nutrition, digestion, growth, metabolism and energy budget of cod have continued, and these results are compared to results of field studies, in net cages and in laboratory tanks.

Changes in the renin - angiotensin - system during smoltification in Atlantic salmon are being studied in cooperation with the Gade Institute. A preliminary morphological investigation seems to show that renin - angiotensin - systems are being activated during the smoltification-process.

Experiments on early acclimatization of rainbow trout to sea water were carried out and related to food uptake, growth rate and mortality.

#### Rearing of marine fish larvae.

The experiments with hatching and rearing marine fish larvae and fry in land situated basins and in plastic bags, was continued. The main effort was this year put on the study of the effect of food density on growth and survival of herring larvae (Atlanto-scandian herring and herring from a local stock in Lindåspollene, north of Bergen) and of capelin larvae. A preliminary experiment was started on predation on fish larvae, competition from other organisms and the competition strength of different fish larvae (herring, cod and plaice) at equal feeding conditions. Development of new techniques in the field of mass culture of marine fish larvae, mainly cod, is started.

#### Other projects.

A salmonid release project which started in 1976 was interrupted by the detection of IPN virus, and no fish were released in 1978.

An experiment to assess the effectiveness of several anti-fouling impregnants for net pens started in May 1975 in cooperation with a paint manufacturing company (Monopol A/S, Bergen). Test quadrangles of net impregnated with different anti-fouling agents have been placed on a locality outside Bergen. The experiment will continue in 1979.

The possibilities for commercial culture of blue mussels, Mytilus edulis, at the west coast of Norway was surveyed. Studies were initiated on settling of larvae, growth rate and techniques for commercial culture.

Short-term and long-term keeping of live saithe in net pens in storage for the fishing industry was studied. The effects of handling stocking density, fouling and the healing of bruises was investigated.

Investigations on locating the optimal sites for growing European oysters, Ostrea edulis, were initiated.

Hydrographic and other environmental factors at the coast of the county of Finnmark were systematically investigated in order to map localities fit for farming of salmonids and storing of live saithe.

#### Poland

(J. Wiktor)

During 1978, the following experiments were conducted in Poland:

- a) Incubation of roe of rainbow trout and sea trout in natural Baltic sea water;
- b) rearing of fry in Baltic sea water;
- c) breeding of rainbow trout in keep-nets during the first and second season in the Baltic Sea.

Observations comprised the biology and development, growth rate, utilisation of several manure types, diseases in brackish waters.

The observations were conducted in principle in conformity with the technical conditions. The results obtained are indicating the possibility of application of some of the investigation methods on a technical scale.

Substantial difficulties were met by suppressing bacterial diseases of of septicaemial type in the rainbow trout culture. This problem will be the main subject of research during 1979.

Further work is aimed at the closing up of a full cycle of culture (ripening of spawners, spawning, incubation of roe and rearing of fry) in brackish water.

Promising results at laboratory scale were already obtained in 1978.



### Portugal

(M.J. de Figueiredo)

Laboratory experiments on the culture of early larvae of Mugilid fishes (Mugil cephalus, Mugil auratus and Mugil capito) captured in the estuary of the River Sado, have been carried out at the Instituto Nacional de Investigaçã das Pescas, in order to stock the ponds of a tidal fish culture pilot station in the spring of 1979.

The growth of the larvae, reared under different diets and concentrations and at temperatures varying mainly between 18°C and 21°C, was determined and compared with the values obtained by sampling periodically the same species in the wild.

These preliminary experiments are to be continued but they already point to the advantage of the rearing under artificial conditions which appear to induce a significant faster growth rate, particularly during the slow growing cold season when the water temperature in the estuary varies between 10°C and 14°C.

### Spain

(M. Torre)

#### Algae

Research on the Gelidium stocks were continued at the north coast of Spain (Gulf of Biscay) in order to study the feasibility of possible culture or better management of the stocks. The aim is to avoid the extinction of that species which is the main source for certain Spanish industries working on chemicals from seaweeds.

#### Molluscs

Studies on the culture of Venerupis pullastra, V. decussata, Ostrea edulis and Pecten maximus were continued in the Laboratory of La Coruña of the Spanish Institute of Oceanography. These studies were made on sand beds and also by hanging cultures from rafts.

Some studies were also started on the production of epifauna on the mussel ropes of an average mussel raft. The study of the digestive glandula disease of the flat oyster in hanging cultures was continued.

The Instituto de Investigaciones Pesqueras, Barcelona, has initiated experiments with the culture of Haliotis discus and H. discus hannai, and it was observed that the best results were obtained by using Laminaria, Ulva and Dictyopteris as food. Also studied were the length, width and height of the shell and the width and number of respiratory holes.

The experiments made by the same Institute with Octopus vulgaris gave a very high growth rate and food conversion index. The work carried out on the reproduction of this species shows very satisfactory results when the spawners were given a photoperiod with long time of light (16/24 h of light) and by using artificial induction techniques. In that way one obtained five spawnings in the laboratory during the ordinary spawning season in the natural environment. A very clear correlation between the length of the embrion development time and the water temperature in the tanks was observed. There were certain difficulties with the feeding of the newly born that made us to change to the study of another species, Eledone moschata, which is easier to feed.

Some experiments were also made on the culture of Sepia officinalis in some ponds of a salt pond near Cadiz. 2 300 specimens were obtained from eggs; the average

weight after 5 months was high (300 g), but the presence of predators had a great effect on the survival which was very low.

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### Crustaceans

Studies were continued on Palaemon serratus and Penaeus kerathurus in the Laboratorio del Mar Menor, (Murcia) of the Spanish Institute of Oceanography. Palaemon serratus was kept in 1 000 l tanks with sea water of 38‰ salinity and a temperature of 22-23°C. Naupliae of Artemia salina was used as feed and the survival rate from larvae I until post-larvae ranged between 55 and 93%.

Experiments were also carried out in 20 l tanks with sea water of 44‰ salinity with different density of larvae I and it was observed that with higher larval density the length of the larval period increased.

Experiments were made with different food as alternative to Artemia but with no good results.

Spawning tests were made with Penaeus kerathurus, thus obtaining 94% females with ripe ovaries and spawning. The larvae were kept in three different salinities: 44‰, 37‰ and common Mediterranean water. The hatching percentage was investigated in ten different salinities between 26.2‰ and 46.7‰ of which the best results were obtained with 29.9-32.1‰.

The best nauplius survival was in 37.5‰ sea water and the best protozoa survival with 30‰.

In the Instituto de Investigaciones Pesqueras the growth and survival of 1 000 specimens of Penaeus kerathurus were studied which were the second generation born in the laboratory. During this study the relation with different physical and chemical factors of the sea water was controlled and investigated.

### Fishes

In the laboratory of the Instituto español de Oceanografía del Mar Menor the research on Mugil sp., Dicentrarchus labrax, Sparus auratus and Pagellus mormyrus were continued.

Concerning Sparus auratus the spawners had been reared from egg, which means that the second culture generation was obtained from those fish. The tanks were of 7 cubic metres and the food supplied was Brachionus plicatilis, Artemia naupliae and crushed Carcinus maenas. The survival rate from egg to the 67th day was approximately 20%. The water temperature was between 14.6°C and 19°C. Other data will be published for the forthcoming Statutory Meeting of ICES.

The Instituto de Investigaciones Pesqueras has tested the efficiency of certain hormones, as the carp hypophysis and the endogenous factor FSH/LH-RH in the processes of ripening of the gonads of the common sole (Solea solea). The influence of the light-darkness period and its variation during the development of this species was also studied.

The average growth on young soles fed with mussels (M. edulis) and crab (Macropipus depurator) was 27.7 cm, with a survival rate of 54% after two years of observation.

The influence of the food on the growth and behaviour of fingerlings of Sparus auratus was investigated.

How the form of the tanks and the density of individuals per tank affects the growth were also studied, as well as the survival and behaviour of S. auratus. The results show that the rectangular tanks are better than the circular ones.

Studies were begun on Dicentrarchus labrax in captivity. The circadian variation of some metabolites in various organs and in the hypophysis were studied in Caraussius auratus. The results allowed the determination of the amino acids present in the plasma of those species, and it was possible to establish the circadian rhythms of each of the species.

Sweden  
(B. Holmberg)

The number of fishfarms in Sweden is more than 500, but most of them are very small. They can be divided into the following categories:

1. Private fishfarms The production will be used mostly for stocking purposes and sport fisheries. About 25 of the fishfarms are producing 80 % of the fish. The most important species are rainbow trout, lake trout and char.

2. Fishfarms operated by hydroelectric power companies According to the Water Law the hydroelectric power companies have to compensate for the damage in the rivers on sea running fish species. About 20 fishfarms produce 2 million salmon smolts each year for restocking.

3. Fishfarms for production of fish for consumption Farming of fish for consumption is not very common and the annual production is about 200 tons of rainbow trout. Most fish will be produced in floating net-cages during the summer period.

According to the Water Law about 2 millions of salmon smolts are stocked every year in the Baltic. In 1979 about 550 000 extra salmon and sea trout smolts will be released. Sea-trout have been stocked in coastal areas with good results for the local commercial and sport fisheries. Short migrating strains of sea trout have been tested in certain areas. The most important task is to increase the survival of the smolts to increase the yield. The effects of smoltsize, time of releasing, adaptation to seawater and natural food are investigated.

Farming of rainbow trout for consumption have been tested in floating net cages in lakes and some coastal areas. It is not possible to culture fish in net cages during the winter because of the low water temperatures. To eliminate this problem fish farming in recirculated systems have been analysed, specially by private companies.

The possibility of using cooling water from nuclear power plants for fish farming are under investigation. A pilot fishfarm have been constructed in connection with a power plant and brackish water (7 ‰) is used. Research programme: rearing technique for salmon, sea trout, rainbow trout and eel, growth and nutrition, diseases, testing the suitability of produced fish for stocking purposes or consumption.

A few pilot mussel farms are operating on the west coast. The ecological effect of musselculture is studied. New products of mussels will be investigated. Farming of oysters (Crassostrea gigas) are under testing.

United Kingdom

1. England (C.E. Purdom)

Fisheries Laboratory, Lowestoft

Husbandry Research

Turbot continued to receive priority rating and in particular the egg and larval development aspects.

Photoperiod control of spawning has now advanced to the stage where fertile eggs can be produced at any time during the year. Accelerated first maturation was also achieved by photoperiod manipulation. Females were sexually mature up to eighteen months earlier than in controls and males twelve months earlier. Turbot stocks, in particular, were badly hit by disease during the year, and a significant factor was probably the cramped and difficult circumstances under which the fish were held. Biochemical work on steroid analysis progressed with the development of a radio immuno assay for sex hormones with a sensitivity adequate for sexing immature fish.

The larval fish rearing programme was again restricted to work with turbot and cod and dab programmes were deferred. Egg quality from our turbot broodstocks was of uneven nature and a syndrome often associated with poor eggs - water belly - spoiled many trials. This larval condition is well known but has not bothered us for several years. No infective agent has yet been identified.

The routine production of pre-weaning larvae is now well established with survivals of above 20% the norm. Comparative weaning trials suggest an advantage to moist diets but of greater importance was the condition of the larvae.

A diet of Artemia nauplii alone still appears to be nutritionally inadequate for turbot and, in any case, it would be an advantage to be able to dispense with it. Trials using rotifers alone showed that they would support growth of turbot larvae to 15 mm in length and a further refinement of the weaning processes could obviate the need to use Artemia.

The identification of long chain fatty acids as an obligatory component of larval diets seems now to be well established and further work will be done to screen species of algae for their lipid contents. Work with liposomes rich in long chain fatty acids ran into problems with "water belly".

The reciprocal hybrids between turbot and brill were reared and compared to the straight species. Survival to metamorphosis was excellent for brill/turbot and very good for turbot/brill. If market considerations were not adverse, the brill/turbot hybrid would be the most promising type for farming.

Post metamorphosis rearing work has been severely limited by lack of space. A joint project has been started with BOC on the use of trash fish and moist diets for trout in fresh and sea water. This work is being performed at BOC sites in Cumbria and Ayrshire.

Some analysis of previous work with dietary lipid suggests a protein-saving effect of about 30% when 6% lipid is added to diets of trash fish in turbot nutrition. Some adverse consequences, however, were apparent.

Marine fish genetics work was limited to the production of sex-reversed turbot and the induction of autoimmune sterilization. In both cases on-going studies of hormone levels will be necessary to assess the level of success.

The genetic study of protein variation in plaice was completed. The project included an assessment of the manner of inheritance, the consequences of gynogenesis and induced triploidy and some use of the enzyme systems in discriminating natural populations of plaice.

A start has been made on the Water Quality Survey of farms in England and Wales. The field work should be complete by Autumn 1979.

Work on marine cultivation of salmonids is somewhat restricted due to space and water limitations. A comparison of two strains of rainbow trout is being made, with respect to changes in the Na<sup>+</sup> plasma levels following transfer to salt water.

Salmonid genetic programmes have received the greatest attention during the year partly because of the basic nature of broodstock holding needs and partly because of the available facilities at Sacrewell and elsewhere. The maintenance of broodstocks remains an obligatory commitment.

Sex-reversed male trout are now two years old and sexually mature. Contemporary studies with gynogenesis show that all diploid gynogenetic trout are female with the implication that sex control may be of an XX female, XY male type. If this is so, crosses between sex-reversed males and normal females will give all-female broods of offspring. Crosses will be set up to examine the genetic nature of 100 males from the reversed group.

Further sex-reversed fish of the 1978 year class are being reared and refined tests for sex using squash preparations have been developed to assist these programmes on the genetics of sex in salmonids.

#### Disease studies

The Fish Disease Laboratory at Weymouth and the Fish Cultivation Group at Lowestoft have recently been united into a single Fish Cultivation Section and future reports will be incorporate. Principal areas of disease work in 1978/79 have been:

##### A. Bacteriology

- (i) Completion of the 1978 furunculosis vaccine trial.
- (ii) Completion of a bacteriophage typing scheme for Aeromonas salmonicida.
- (iii) Detailed studies on bacteria causing BKD have been started and some of the isolates partially characterised.
- (iv) Studies on pathogenic Vibrio strains isolated from marine fish farms have been expanded and an experimental polyvalent vaccine produced for trial at Lowestoft.
- (v) A new bacterial pathogen of lobsters has been isolated and characterised.



## B. Virology

- (i) Further characterisation and differentiation of IPN-like shellfish viruses and serological comparisons with IPN virus and other related viruses.
- (ii) Studies on the possibility of active immunization of rainbow trout fry against IPN disease.
- (iii) Studies on the relationships between the two eel rhabdoviruses and other fish rhabdoviruses.

## C. Pathology and Immunology

- (i) Histopathological investigations of fish and shellfish including studies on furunculosis, bacterial kidney disease (BKD) and SVC; diseases of uncertain aetiology, ie proliferative kidney disease (PKD), black patch necrosis (BPN), stress factors and abnormalities in shellfish.
- (ii) Epideminology studies which entailed monitoring fish on and below farms for important fish diseases such as BKD, PKD and IPN.
- (iii) Diagnostics and advice associated with statutory duties of the Diseases of Fish Act, 1937.
- (iv) Mycological investigations into treatments and medications for fungus diseases of fish.
- (v) Identification of the immune mechanism in trout against IPN and furunculosis; passive immune studies and analysis of vaccination methods for fish.

## 2. Scotland

(A.L.S. Munro)

The report comprises information from Heriot Watt University, Institute of Marine Biochemistry, Marine Laboratory, Scottish Marine Biological Association, Unit of Aquatic Pathobiology, (Stirling University,) White Fish Authority.

### Salmon and Trout

The process of feminisation of juvenile salmonids by treatment of the juveniles with dietary  $17\beta$  oestradiol has been further refined and the production of all male stocks by dietary  $11 - \alpha$  testotosterone and  $17\alpha - \text{methyltestosterone}$  investigated in greater detail. The pairing of fish sex reversed by the latter process with normal females has been shown to result in all female stocks.

Investigations of grilse maturation have shown that during their second sea year, potential grilse suffer weight losses, despite heavy feeding at least seven months before spawning and before they can be recognised by fish farmers.

They can, however, be identified, even earlier, by their weight/length characteristics. It has further been shown, and confirmed by determination of the levels of circulatory steroids that the "decision" to mature is made during the autumn of the previous year. Food deprivation at that time results in a statistically significant increase in the proportion of the stock maturing as grilse in the second year.

A commercial single-cell protein preparation has been fed to fresh and sea water stages of salmon over a 12 month period at levels of 25, 50 and 75% of the total protein in the diet. Even at the highest level, growth was equal to that with a diet where the protein was wholly composed of a fish protein preparation. No pathological symptoms were detected.

Nephrocalcinosis, a pathological condition causing stone formation in the kidney, has been experimentally induced in rainbow trout when normal commercial diets are made deficient in magnesium. A minimum requirement for rainbow trout was determined as  $0.5\text{g Mg}^{++}/\text{kg}$  of diet. It has also been shown that high levels of  $\text{CO}_2$  dioxide ( $>20\text{ mg/l}$ ), such as occur in intensive culture systems when pH commonly drops below 7, also results in nephrocalcinosis.

A study of the effects of high salt content commercial diets fed to trout prior to their transfer to seawater showed a substantial reduction in transfer mortality.

Trials with a recall feeding system for free ranging rainbow trout in a fresh water loch have suggested that it is possible to develop recall to a feeding station as the sole or supplementary feeding regime.

Proliferative kidney disease was identified as the cause of a minor mortality in a farmed population of 1st summer salmon parr of Norwegian origin. The condition could not be found in adjacent tank populations of Scottish derived populations of salmon parr.

A novel disease causing acute pancreatitis in the first 3-7 months of the sea life of salmon smolts recurred for the 3rd successive year. Mortality is variable, from <1 - 10%, but more serious is the observation that most fish show a growth check and some, from 5 - 30%, may grow too slowly to be useful for commercial culture. Smolts from the hatchery supplying the sole sea site where this disease is present did not develop the condition at other seawater sites. Despite the failure of microscopic and culture methods to demonstrate an infectious pathogen field evidence suggests an infectious aetiology.

#### Dover Sole

Batches of sole from the 1977 batch have been ongrown at rates in excess of 1% per day. Larger fish favour a temperature of 14° whereas nursery size fish grow well at 18-19°. More than 50% of fish now exceed 250g at February 1979. Growth checks due to outbreaks of a skin disease of unknown aetiology, called Black Patch Necrosis (BPN), have had a significant retarding effect.

Photoperiod control allowed at least a 50 day advancement of spawning in 1978. Considerable savings in the time to wean metamorphosed fish to artificial diets were achieved with the 1978 batch. This also resulted in considerable saving in labour spent producing live diets. The oldest group now average 60g and are growing at 2% of body weight per day. This superior growth performance is attributed to keeping BPN under control by the use of a sand layer in the fish tanks.

Studies of the use of tasteattractants have shown that in older fish (>50g) betaine alone is sufficient but younger fish (2g) require a more complex mixture of attractants.

Attempts to rear sole to metamorphosis on artificial diets gave mixed success. Some 20% survival was achieved with the artificial diet compared to 75% with Artemia.

### Turbot

Low egg viability continues to be a serious problem. Weaning started at the smaller size of 20 mm, and its duration was reduced to 21 days. The earliest hatched 78 turbot achieved 40g by October when they were transferred from the hatchery for overwintering in sea water cages (no heating) to ascertain their overwinter growth performance. High stocking densities, 29 and 56 kg/m<sup>3</sup> have been achieved with the 77 year class of turbot. Inosine and inosine-5'-monophosphate are specific feeding stimulants for turbot.

A programme to define the water quality requirements for sole and turbot, and the necessary technology, in recirculation systems has been started.

A new herpes virus disease of turbot has been recorded. The virus appears to be endemic in wild stock and is capable of causing heavy mortalities in young farmed fish.

### Tilapia

The Unit of Aquatic Pathobiology are continuing to develop a programme of work, funded by the Ministry of Overseas Development, on defining parameters limiting the intensive culture of Tilapia spp. A pilot warm water plant is being constructed at Stirling to verify field results from experimental farms in Kenya. Stock density studies and nutritional evaluations under different temperature and oxygen regimes have allowed a broad definition of the ideal and limiting conditions for Tilapia culture. The production of all male fry has been shown to have serious potential for improving yields from intensive culture systems.

### Molluscs

Pectinid sprat was obtained from artificial collectors and kept in cages to study their growth and the feasibility of cultivation. Experiments were continued to compare growth and fattening of Pacific oysters at different levels on the shore and suspended from a raft in cages.

Samples of molluscs and their seed for export and import were checked for freedom from pest and diseases.

### Crustaceans

Gaffkemia disease was identified for the first time in a lobster impoundment on the Scottish east coast. No stocks remain and the impoundment of lobsters in the establishment has been discontinued.

### Pollution by oil

Recently it has been shown that the carcinogen yielding enzyme, aryl hydrocarbon hydroxylase (AHH), can be induced in fish when they are exposed to Prudhoe Bay crude oil. Work has commenced to detect and estimate the amount of AHH activity in fish taken from oil contaminated and other regions of the Scottish Coast and North Sea. The object is to see whether the level of AHH activity can be used as an indicator of the quantity of carcinogen present in fish.

### U.S.A.

(A.C. Longwell + J. Ryther)

### MARICULTURE PROJECTS SUPPORTED UNDER THE U.S. SEA GRANT PROGRAM\*

#### Finfish

##### Salmon

At the University of Alaska researchers are examining genetic interactions of Auke Creek hatchery pink salmon with natural spawning stocks. The genetics of egg and fry characteristics is being examined; also, effects of intra-species hybridization on hatchery swimup behavior and on susceptibility to bacterial disease. A dry-salmon ration of readily available local

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\*Because these Sea Grant projects cover such a diversity of topics in so many geographic areas on so many diverse groups, it was not practical here to report on them in any depth. Additional information can be obtained by communication with researchers involved. Their names and full address can be obtained by contacting the National Sea Grant Program, NOAA, U. S. Dept. of Commerce, Rockville, MD 20852. The less diverse, fewer government projects could be commented on more explicitly. Any desired additional information on any of these is available through B. Drucker, National Marine Fisheries Service, NOAA, U. S. Dept. of Commerce, Washington, DC 20235.

products and underutilized species is being formulated. A comparison is being made of the growth of young pink salmon on oil-contaminated food with growth on uncontaminated food.

At the University of Washington five projects are conducted on salmon with the following objectives: (1) to develop management strategies for increased survival of wild and hatchery stocks of Puget Sound; (2) to ascertain effects of various hatchery incubation systems on chum salmon fry quality and migration; (3) to develop an improved dry diet for young salmon; (4) to develop a diet specifically for rainbow trout and coho salmon broodstock for high quality gamete production; (5) to analyze '78 and '79 adult salmon returns from experimental lots of coho and chinook marked and released in '75, '76, and '77. Puget Sound now has a major salmon pen-rearing industry.

An effort is being made to develop broodstock particularly suited to marine pen culture. In addition, thyroid control of salmon smoltification is being studied in efforts to reduce pair-reversion.

Researchers at Oregon State University are attempting to restore the Oregon chum salmon resource. This involves the continued artificial propagation of Whiskey Creek stock and further development of the Oregon chum salmon broodstock.

The endocrine control of salmonid smoltification and seawater adaptation is also being researched at the University of California (Berkeley). At Humboldt State University (California) biologists are investigating the possibility of significantly increasing numbers of chinook salmon returns by artificially imprinting and attracting the juveniles.

At the University of Rhode Island researchers are identifying factors that limit economical production of salmonids in water reuse systems. The commercial viability of Atlantic salmon ocean ranching in New England is being considered.

Studies have begun at the University of Maine and University of New Hampshire on the antigenic and genetic characteristics of the infectious



pancreatic necrosis virus of salmonid. Results could facilitate development of an effective vaccine. At the University of Idaho a study has been initiated on means of abolishing any carrier states of furuncularis and bacterial kidney disease in Pacific salmon.

Studies on the preservation of salmonid gametes continue at the University of Minnesota. Sperm can now be frozen and thawed and retain near normal viability. There has also been some success in recovery of frozen salmonid eggs.

#### Other Finfish

Suitable diets for walleye culture are being investigated at Cornell University. At the University of Wisconsin the economic potential of culturing yellow perch is being examined. There are five commercial yellow perch operations in Wisconsin. Bass and bass-perch hybrids are a subject of research in North Carolina. The potential of eel culture in this state is also being evaluated.

Work on the culture of baitfish continues at the University of Hawaii. The objective is to develop a cost-effective topminnow culture system capable of producing large quantities of live baitfish required for the skipjack tuna industry.

#### Crustaceans

##### Shrimp

At Texas A&M and the University of Houston emphasis is on production systems and determination of which species can be grown successfully in ponds along the Texas coast. Being researched are: the role lipids play in the maturation of penaeid shrimp, nutritional and biochemical studies relating to penaeid shrimp maturation, and development of a comprehensive health management program which will optimize production capabilities. The economics of shrimp mariculture is also under study.

### Freshwater Prawns

In South Carolina researchers are investigating the commercial feasibility of culturing freshwater prawns (Macrobrachium) in the southeast U.S. Nutritional studies are being conducted there and also at Rutgers University.

A commercial freshwater prawn industry has developed in Hawaii. Research at the University of Hawaii is related to the needs of this industry. The state of Hawaii is also conducting research and advisory services for the industry, which has expanded over 110 acres.

### Lobster

At the Bodega Bay marine laboratory, University of California, the isozyme variations in lobster species are being described with plans to expand research to shrimp and crabs. An effort is being made to develop a technology that should enable domestication of desirable crustaceans. Researchers are assessing the benefits and problems involved in using thermal effluents from coastal power stations as an economical source of heat in the culture of American lobsters.

At Woods Hole Oceanographic Institution investigators are evaluating the utilization of carbohydrate and protein by post-larval lobsters for the purpose of defining an optimum protein:carbohydrate ratio. At the University of Maine minimal cost lobster rations based on analysis of lobster dietary intake and metabolic studies are being formulated and evaluated. In another study Maine researchers are developing a vaccination peg which will immobilize the lobster claw and inject a gaffkemia vaccine into the tissue.

### Crayfish

Pond culture of crayfish is under study at Louisiana State University.

### Brine Shrimp

At the University of Rhode Island chemists are analyzing and comparing available strains of brine shrimp in respect to their biochemical characteristics and ability to support survival and growth of young fish and crabs.

The economic feasibility of producing brine shrimp in the St. Croix (Virgin Islands) artificial upwelling system is being determined.

#### Decapod Fertilization

The basic mechanisms of decapod fertilization are studied at the University of California (Riverside).

#### Shellfish

##### Controlled and Waste Recycling Mariculture Systems

The largest, major effort in molluscan culture supported by Sea Grant is the development of the controlled mariculture system by researchers at the University of Delaware. The program is dealing with many facets: nutrition, engineering, microbiology, shell formation, and mineral requirements. Several industries are partners in this program. Presently, a \$1.2 million mariculture laboratory is being constructed, which will be used as a pilot operation to demonstrate controlled environmental systems for molluscan culture.

At Woods Hole Oceanographic Institution investigators are assessing the biological and economic feasibility of marine bivalve culture in waste recycling aquaculture systems and as a means for tertiary sewage effluent treatment. A simple model is being made of algal production, shellfish growth, contaminants uptake, and depuration by bivalves in a waste recycling system.

#### Oysters

Biologists at Oregon State University are encouraging commercial oyster growers to adapt techniques developed at the university. These include the rearing of cultchless spat. There is available an experimental demonstration of selective breeding and broodstock management of Pacific oysters. The commercial potential of the exotic Crassostrea rivularis is being evaluated.

Research is being conducted at the University of Washington on hybrid strains of oysters with resistance to summer mortalities that occur both in Japan and along the U.S. west coast.

At the Virginia Institute of Marine Science studies continue on artificial diets for oysters. Oyster strains are being selected there for resistance to the disease Dermocystidium marina.

#### Clams

The genetics and breeding structure of clams, Mercenaria spp, are being studied at George Mason University. Research at the Woods Hole Oceanographic Institution is directed at correlating the frequency of genetic markers in natural and hatchery-reared populations of hard clams.

At Oregon State University the biological feasibility of using hatchery-reared clams to supplement natural stocks is being explored. The necessity and feasibility of augmenting hard clam production by seeding are, in addition, being examined for coastal waters along Georgia.

At the University of Washington the effectiveness of plastic netting as a Manila clam attractant is being tested with the idea in mind of increasing survival of planted clams. (Comparisons are also being made between natural setting of mussels in Puget Sound and that on artificial substrates.)

A final analysis and interpretation of data on the culture of clams (Tapes japonica) in an artificial upwelling system is underway.

#### Scallop

Studies are underway to refine hatchery and ocean rearing methods for the purple hinge rock scallop in California (University of California).

### Abalone

The University of California with the California Department of Fish and Game are looking into the scientific and economic feasibilities of enhancing abalone populations in areas of southern California where their populations are depleted. Research is being done on the growth, development, and metamorphosis of abalone.

### Aquaculture Engineering

As part of the Texas A&M shrimp aquaculture program, engineers are testing and revising the initial shrimp growth model. In addition, they are determining the feasibility and economic returns from a management system to monitor and control dissolved oxygen level, water temperature and salinity, ammonia level, and other significant factors for optimal shrimp growth. A major component of the University of Delaware's controlled system mariculture program is the engineering aspects. Work continues to optimize the process and to reduce cost. A third aquaculture engineering project is underway in Hawaii at the Oceanic Institute. The overall objective of this program is to develop cage culture technology in moderately rough marine environments.

### Aquaculture Economic Studies

A major economic project, utilizing talents from five Sea Grant schools, is attempting to develop an enterprise budget simulator for general aquaculture systems. As a part of this program, researchers will conduct an economic analysis for high priority species on problems most relevant to a particular region.

### Aquaculture Socio-Political Studies

The objective of this project at Oregon State University is to document regulations affecting aquaculture production and marketing. Also, an analysis will be made on how institutional arrangements affect aquaculture. Institutional structures in other countries will be examined.

### MARICULTURE PROJECTS SUPPORTED UNDER THE NATIONAL MARINE FISHERIES SERVICE, NOAA

#### Salmon (Seattle and Manchester, Washington, laboratories, NWAFC)

Nutrition research on the Pacific salmon includes evaluation of diets containing alternate sources of proteins, investigation of nutritional diseases, and development of measures of nutritional quality in hatchery salmonids. Disease studies encompass development of prophylactic techniques, definition of immune mechanisms in marine cultured populations, and evaluation of the incidence of bacterial and viral diseases in hatchery salmonids. Physiological research includes development of biochemical methods for determination of status of smoltification and seawater adaptation in hatchery salmonids, and investigations of techniques to exert positive control over the smolting process. Husbandry studies are aimed at the development of improved cost-effective techniques for marine net-pen culture. Genetic studies are presently limited to the delineation of genetic stocks for better management of mixed-stock fisheries.

#### Marine Turtles, Shrimp, and Finfish (Galveston, Texas, Laboratory, SEFC)

Progress has been made in increasing survival rate of marine turtles in captivity by improving diet and holding systems. Several disease treatments have been identified for turtles. White shrimp (Penaeus setiferus) have



been induced to mature and spawn for the first time in captivity but no fertilization took place. Redfish (Sciaenops ocellata) and black drum (Pogonias chromis) were reared successfully in the hatchery. Improvements were made in rotifer culture techniques.

Facilities now include a large greenhouse building for rearing marine turtles. The latest equipment for water treatment has been incorporated into the laboratory's semi-closed culture system.

Oysters (Milford, Connecticut, Laboratory, NEFC)

#### Breeding

A selection program for fast and slow growth in the American oyster, Crassostrea virginica, is continuing into its third year. The first generation of selected offspring has been produced from some 220 selected oysters. Growth rates in oyster larvae and spat from 21 half-sib families were determined and used to calculate heritability estimates. For larval growth rate the estimates ranged from .37 to .57. Heritability estimates for spat growth rate measured at six weeks post-setting averaged .51. Values indicate that selection for growth rate would be successful. The relationship between larval setting order and subsequent spat growth in the American oyster was analyzed. Four separate full-sib families were examined. Results indicate that hatchery selection of earliest-setting larvae should produce faster growing juvenile oysters.

The inbreeding-crossbreeding program on the American oyster continues with some of the 31 full-sib families set up for this purpose yielding spat from crosses of '76 and '77 year-class families. Generally, there

was better survival of larvae to metamorphosis in the 25 outcrossed control families than in the inbred families. In other respects though inbred larvae performed as well as outbred larvae under controlled laboratory conditions. In the forthcoming breeding season inbreds will be test-crossed with one another.

Means of treating effluent water from non-local shellfish now make it possible at Milford to evaluate adequately inter- and intra-species of oysters for direct commercial use or for special breeding programs.

#### Pathology

An ozone-quarantine system has been set up to disinfect effluent of non-indigenous oysters, including larvae and microorganisms of hybrid crosses. Optimal flow rate, contact time, and ultraviolet light exposure necessary to disinfect seawater seeded with bacterial pathogens of oyster larvae have also been determined. Metabolites from two strains of bacteria have been shown to be toxic to oyster larvae. Pathogenic bacteria then need not be actually present in shellfish culture water to cause damage and mortality, but can lodge in hatchery plumbing and slowly release substances harmful to shellfish larvae. By cytochemical procedures it has been determined that two- and three-day-old veliger oyster larvae are capable of disease defense.

#### Bay Scallop and Surf Clam Culture (Milford, Connecticut, Laboratory, NEFC)

Commercially feasible methods for aquaculture of the bay scallop, Argopecten irradians, and the surf clam, Spisula solidissima, are being researched, as conditions for optimal gametogenesis and spawning. Growth studies conducted in the tank farm confirm the biological feasibility of

rearing seed clams in Connecticut to a projected market size of 55 mm by the end of July.

Experiments have been conducted to determine optimal stocking densities for seed-scallop production in a pumped raceway system. More specific calculations of the food requirements of juvenile bay scallops are to be made. In an attempt to optimize growth and handling of young bay scallops in the raceway system scallops were simultaneously maintained suspended in a net and at the bottom. With the cooperation of the Aquaculture Division of the Connecticut Department of Agriculture 10,000 seed scallops have been planted in Connecticut waters.

Marine Algal Foods of Shellfish (Milford, Connecticut, Laboratory, NEFC)

Studies are being done to determine if algae used as molluscan foods can be cultured on a dilute, more economical medium than currently employed. Substantial reduction in concentration of seawater nutrient enrichments appears not to affect yield. Whether the dilute medium can support many serial subcultures without diminishing productivity is still to be determined. Studies on the cryopreservation of micro-algae used in oyster hatcheries continue. Use of cryopreserved live algae could be both convenient and economic in commercial hatchery production. Experimental evidence has been collected which shows that algae have the capacity to develop increasing tolerance to metals on continuous exposure. Such algae grown in contaminated media have adverse effects on oyster development.

In this program 96 strains of bacteria-free micro-algae are regularly maintained on several types of defined media. Strains are available to academic investigators and commercial hatcheries. A pilot-plant algal culture system supplies algae needed as food for projects on molluscan rearing.

## AQUACULTURE TRAINING

Because of the growth of aquaculture in the Pacific northwest U.S., there is a need there for technical personnel capable of dealing with the complex interplay between disciplines in mariculture - personnel prepared to act with proficiency in several specialized roles. To serve that need a program at Oregon State University offers graduate-level opportunities for study in several aquaculture-oriented disciplines combined with opportunities for practical experience in aquacultural production. Also, the University of Alaska is establishing a training program which will enable hatchery technicians to gain practical experience in the many new state and private hatcheries. As part of this program, an on-campus production hatchery will produce fish for the common-property fishery, and serve as a source of self-sustaining funds from the sale of returning salmon.

The University of Hawaii is developing a core of aquaculture courses which can form the base for advanced training and practice in aquaculture. Veterinarians at the University of Pennsylvania are developing a graduate-level course with research experience in aquatic veterinary medicine. The University of Delaware will bring the results of specific Sea Grant-sponsored, industry-oriented research and development programs to interested industrial firms with the primary goal being the demonstration of commercial viability.

A workshop on Aquaculture on the Gulf Coast was organized and held at the Galveston, Texas, Laboratory of the National Marine Fisheries Service. The Training Center at the Milford, Connecticut, Laboratory, NEFC, National Marine Fisheries Service, continues to provide training opportunities for industry and academic personnel in various areas of molluscan aquaculture, as genetics, culture methodology, algal rearing, and larval disease. International training visits during the past year included a Japanese geneticist, two Polish marine biologists, and a French scientist from CNEXO, Brest.

U.S.S.R.

(P. Moiseev)

Investigations on mariculture in the north-eastern Atlantic are carried out by the All-Union Research Institute of Marine Fisheries and Oceanography (VNIRO), Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Atlantic Research Institute of Marine Fisheries and Oceanography (AtlantNIRO) and Baltic Research Institute of Marine Fisheries (PINRO).

In 1978 investigations on artificial rearing of salmon in hatcheries (with release into the sea for feeding), commercial rearing of rainbow trout, coho- and other salmon and bester (hybrid between Beluga and Sterlet), cultivation of invertebrates and algae were developed.

In 1978 VNIRO carried out work on the improvement of the construction of sea fish cages (stretching of bottom part of cage) partial substitution of net bottom by entire polyethylene film); all this increased the efficiency of feeding by 3-4 times. Some aspects of the biotechnique of rearing salmon and sturgeons in cages were studied.

Methods for the control of bacterial diseases of fish reared in cages were worked out. Vaccination of trout, coho- and Baltic salmon gave good resistance to vibriosis. Due to the vaccination against vibriosis, the output of trout yearlings increased to 25 kg per m<sup>2</sup> during four months of rearing.

For the transition of the young beluga and bester to artificial food chironomids were used. Fish were kept in basins with running sea water. During the transition to artificial food, 10.8% of the fish were lost.

In 1978 VNIRO continued investigations on the efficiency of acclimatisation of pink salmon in the north of the European part of the USSR. Pink salmon was acclimatised in the rivers of the Kola peninsula. It was observed that there was a self reproductive population among year classes of odd years.

In even years, returns were low despite the delivery of eggs from the Far East.

PINRO carried out experiments on rearing of coho-salmon in cages with sea water and in fenced-off areas of the sea. The best results for coho salmon were obtained when yearlings were reared in a hatchery (up to June) and then in sea cages. The increase in weight was 610%.

Experiments on the stimulation of growth by adding protosubtilin in food (2.5 kg per 1 kg of food) were carried out with coho salmon; the increase in weight reached 46%.

Work on the creation of hatcheries for mussel culture with full cycle (from larvae to market size) were carried out. In the Barents Sea in order to decrease expenses, the rearing of settling spat was done with the system of wires without floats.

Methods of incubation of eggs of the White Sea herring on artificial spawning grounds were worked out. The survival of herring eggs was 79.2% on artificial spawning grounds.

VNIRO, together with PINRO continued experiments on the culture of Laminaria saccharina in the Barents Sea. New information on the improvement of the biotechnique for Laminaria culture in the White Sea were obtained.

AtlantNIRO carried out experiments on the rearing of beluga bester in brackish water. By autumn, the weight of bester fingerlings averaged 108 g, of beluga fingerlings 171 g and of bester yearlings 510 g.

In 1978 the Baltic Research Institute of Marine Fisheries fulfilled successfully a multiple research programme on mariculture. New food mixtures for trout and salmon S-112 LAT, S-113 LAT and S-113 LAT5 were created. High production output (156 kg/m<sup>2</sup> within 4 months of feeding trout with this food) proved that they were effective.

Investigations of the influence of vaccination against vibriosis were continued. This vaccination could make sea farms much more profitable. The proportion of losses among vaccinated and non-vaccinated fish was 1:7. The influence of the vaccination on the growth and physiological condition was not considerable.

When coho salmon was reared in sea cages the weight of two-year old fish averaged 1 kg, three-year old fish weighed 1.6 kg and several individuals up to 3 kg. Seventy percent of the fish at this age were mature.

Technical and economical characteristics of sea fish cages were improved by the impregnation of nets with native and foreign antifouling substances. Important characteristics of experimental and control cages were similar, while mortality was lower in cages impregnated with these substances.

The work on a circulating system of water supply for fish farms progressed well.

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